

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
10 March 2005 (10.03.2005)

PCT

(10) International Publication Number  
**WO 2005/021928 A2**

- (51) International Patent Classification<sup>7</sup>: **E21B 33/138**, 43/25, 43/08, 43/02
- (74) Agents: **WAIN, Christopher, Paul et al.**; A A Thornton & Co, 235 High Holborn, London WC1V 7LE (GB).
- (21) International Application Number:  
PCT/GB2004/002747
- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (22) International Filing Date: 25 June 2004 (25.06.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
10/650,064 26 August 2003 (26.08.2003) US
- (84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- (71) Applicant (*for all designated States except US*): **HAL-LIBURTON ENERGY SERVICES, INC.** [US/US]; P.O. Box 1431, Duncan, OK 73533 (US).
- (71) Applicant (*for MW only*): **WAIN, Christopher, Paul** [GB/GB]; A.A. Thornton & Co., 235 High Holborn, London WC1V 7LE (GB).
- Published:**  
— *without international search report and to be republished upon receipt of that report*
- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): **NGUYEN, Philip, D.** [US/US]; 1107 West Jones Avenue, Duncan, OK 73533 (US).
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: PRODUCTION-ENHANCING COMPLETION METHODS

(57) Abstract: The present invention relates to improved methods for completing well bores along producing zones while controlling formation sands and increasing surface area available for production. Some embodiments of the methods of the present invention provide methods of controlling the migration of formation sand in a well bore and increasing surface area for well production comprising the steps of hydr jetting at least one slot into a zone along a well bore; and, placing a consolidation material comprising particulates into the slot.

## PRODUCTION-ENHANCING COMPLETION METHODS

### 1. Field of the Invention.

The present invention relates to improved methods for completing well bores along producing zones and, more particularly, to methods for completing well bores along producing zones while controlling formation sands and increasing surface area available for production.

### 2. Description of the Prior Art.

One completion method commonly used along a producing zone of a well bore involves gravel packing. Such gravel packing treatments are used, *inter alia*, to reduce the migration of unconsolidated formation particulates into the well bore. One common gravel packing operation involves placing a gravel pack screen in the well bore and packing the surrounding annulus between the screen and the well bore with particulates referred to as "gravel" that have a specific size designed to prevent the passage of formation sand. The gravel pack screen is generally a filter assembly used to support and retain the gravel placed during gravel pack operations. A wide range of sizes and screen configurations are available to suit the characteristics of the gravel pack sand used. Similarly, a wide range of sizes of gravel is available to suit the characteristics of the unconsolidated or poorly consolidated particulates in the subterranean formation. The resulting structure presents a barrier to migrating sand from the formation while still permitting fluid flow. When installing the gravel pack, the gravel is carried to the formation in the form of a slurry by mixing the gravel with a transport fluid. Gravel packs act, *inter alia*, to stabilize the formation while causing minimal impairment to well productivity. The gravel, *inter alia*, acts to prevent the particulates from occluding the screen or migrating with the produced fluids, and the screen, *inter alia*, acts to prevent the gravel from entering the production tubing. While gravel packs have been successfully used to control the migration of formation sands, their placement reduces the available diameter of a well bore due to the physical size of the screen and the resulting gravel annulus.

The screen assemblies used in gravel packing operations may also be used independently to control unconsolidated formation sands. Some of the early screen technology dictated that the screens had to be small enough to pass through the smallest diameter of the well bore on the way to its desired placement location where the diameter of

the well bore may actually be larger. Developments in technology have lead to expandable screens such that a relatively small size or small diameter screen may be placed in a desired location along the well bore and then expanded to accommodate the actual size of the well bore at the point of placement.

Another completion method along a producing zone of a well bore, known as hydrajetting, involves the use of hydraulic jets, *inter alia*, to increase the permeability and production capabilities of a formation. In a common hydrajetting operation, a hydrajetting tool having at least one fluid jet forming nozzle is positioned adjacent to a formation to be fractured, and fluid is then jetted through the nozzle against the formation at a pressure sufficient to form a cavity, or slot therein to fracture the formation by stagnation pressure in the cavity. Because the jetted fluids would have to flow out of the slot in a direction generally opposite to the direction of the incoming jetted fluid, they are trapped in the slot and create a relatively high stagnation pressure at the tip of a cavity. This high stagnation pressure often causes a microfracture to be formed that extends a short distance into the formation. That microfracture may be further extended by pumping a fluid into the well bore to raise the ambient fluid pressure exerted on the formation while the formation is being hydrajettted. Such a fluid in the well bore will flow into the slot and fracture produced by the fluid jet and, if introduced into the well bore at a sufficient rate and pressure, may be used to extend the fracture an additional distance from the well bore into the formation.

### SUMMARY OF THE INVENTION

The present invention relates to improved methods for completing well bores along producing zones and, more particularly, to methods for completing well bores along producing zones while controlling formation sands and increasing surface area available for production.

Some embodiments of the present invention provide methods of controlling the migration of formation sand in a well bore and increasing surface area for well production comprising the steps of hydrajetting at least one slot into a zone along a well bore; and, placing a consolidation material comprising particulates into the slot.

Other embodiments of the present invention provide methods of increasing production from a zone along a well bore comprising the steps of hydrajetting at least one slot into the

zone along the well bore; and, placing a consolidation material comprising particulates into the slot.

Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

### **DESCRIPTION OF PREFERRED EMBODIMENTS**

The present invention relates to improved methods for completing well bores along producing zones and, more particularly, to methods for completing well bores along producing zones while controlling formation sands and increasing surface area available for production.

In some embodiments of the methods of the present invention an isolated zone along a well bore is hydrajetted to produce at least one slot, and a consolidating material comprising a proppant is forced into the slot.

Hydrajetting basically involves the use of a tool such as those described in U.S. Patent Nos. 5,765,642, 5,494,103, and 5,361,856, the relevant portions of which are herein incorporated by reference, to create a path, known as a "slot," into the formation from the well bore. In some embodiments of the present invention, the hydrajetting tool is used to create slots substantially uniformly around the well bore circumference. Forcing the consolidating material comprising a proppant into the slot causes the slot to continue to grow further into the formation.

Consolidating materials suitable for use in the methods of the present invention include resinous materials and tackifying materials. The consolidation material comprising proppant not only acts, *inter alia*, to maintain the integrity of the hydrajetted slots; it may also act as a sand control treatment by controlling the migration of formation sands.

Where a resin consolidation material is used, it may be a curable resin. Resin-type consolidation materials aid in the consolidation of the proppant and formation sands. Such consolidation may be desirable to reduce proppant flow-back. Suitable such resin consolidation materials include, but are not limited to, two-component epoxy-based resins, furan-based resins, phenolic-based resins, high-temperature (HT) epoxy-based resins, and phenol/phenol formaldehyde/furfuryl alcohol resins.

Selection of a suitable resin consolidation material may be affected by the temperature of the subterranean formation to which the fluid will be introduced. By way of example, for

subterranean formations having a bottom hole static temperature ("BHST") ranging from about 60°F to about 250°F, two-component epoxy-based resins comprising a hardenable resin component and a hardening agent component containing specific hardening agents may be preferred. For subterranean formations having a BHST ranging from about 300°F to about 600°F, a furan-based resin may be preferred. For subterranean formations having a BHST ranging from about 200°F to about 400°F, either a phenolic-based resin or a one-component HT epoxy-based resin may be suitable. For subterranean formations having a BHST of at least about 175°F, a phenol/phenol formaldehyde/furfuryl alcohol resin may also be suitable.

One resin consolidation material suitable for use in the methods of the present invention is a two-component epoxy based resin comprising a hardenable resin component and a hardening agent component. The hardenable resin component is comprised of a hardenable resin and an optional solvent. The solvent may be added to the resin to reduce its viscosity for ease of handling, mixing and transferring. It is within the ability of one skilled in the art with the benefit of this disclosure to determine if and how much solvent may be needed to achieve a viscosity suitable to the subterranean conditions. Factors that may affect this decision include geographic location of the well and the surrounding weather conditions. An alternate way to reduce the viscosity of the liquid hardenable resin is to heat it. This method avoids the use of a solvent altogether, which may be desirable in certain circumstances. The second component is the liquid hardening agent component, which is comprised of a hardening agent, a silane coupling agent, a surfactant, an optional hydrolyzable ester for, *inter alia*, breaking gelled fracturing fluid films on the proppant particles, and an optional liquid carrier fluid for, *inter alia*, reducing the viscosity of the liquid hardening agent component. It is within the ability of one skilled in the art with the benefit of this disclosure to determine if and how much liquid carrier fluid is needed to achieve a viscosity suitable to the subterranean conditions.

Examples of liquid hardenable resins that can be used include, but are not limited to, organic resins such as bisphenol A-epichlorohydrin resins, polyepoxide resins, novolak resins, polyester resins, phenol-aldehyde resins, urea-aldehyde resins, furan resins, urethane resins, glycidyl ethers and mixtures thereof. The liquid hardenable resin used is included in the liquid hardenable resin component in an amount sufficient to consolidate particulates. In some embodiments of the present invention, the resin used is included in the liquid

hardenable resin component in the range of from about 70% to about 100% by weight of the liquid hardenable resin component.

Any solvent that is compatible with the hardenable resin and achieves the desired viscosity effect is suitable for use in the present invention. Preferred solvents are those having high flash points (most preferably about 125°F) because of, *inter alia*, environmental factors. As described above, use of a solvent in the hardenable resin composition is optional but may be desirable to reduce the viscosity of the hardenable resin component for a variety of reasons including ease of handling, mixing, and transferring. It is within the ability of one skilled in the art with the benefit of this disclosure to determine if and how much solvent is needed to achieve a suitable viscosity. Solvents suitable for use in the present invention include, but are not limited to, butylglycidyl ethers, dipropylene glycol methyl ethers, dipropylene glycol dimethyl ethers, dimethyl formamides, diethyleneglycol methyl ethers, ethyleneglycol butyl ethers, diethyleneglycol butyl ethers, propylene carbonates, methanols, butyl alcohols, d'limonene and fatty acid methyl esters.

Examples of the hardening agents that can be used in the liquid hardening agent component of the two-component consolidation fluids of the present invention include, but are not limited to, amines, aromatic amines, polyamines, aliphatic amines, cyclo-aliphatic amines, amides, polyamides, 2-ethyl-4-methyl imidazole and 1,1,3-trichlorotrifluoroacetone. Selection of a preferred hardening agent depends, in part, on the temperature of the formation in which the hardening agent will be used. By way of example and not of limitation, in subterranean formations having a temperature from about 60°F to about 250°F, amines and cyclo-aliphatic amines such as piperidine, triethylamine, N,N-dimethylaminopyridine, benzyldimethylamine, tris(dimethylaminomethyl) phenol, and 2-(N<sub>2</sub>N-dimethylaminomethyl)phenol are preferred with N,N-dimethylaminopyridine most preferred. In subterranean formations having higher temperatures, 4,4-diaminodiphenyl sulfone may be a suitable hardening agent. The hardening agent used is included in the liquid hardening agent component in an amount sufficient to consolidate particulates. In some embodiments of the present invention, the hardening agent used is included in the liquid hardenable resin component in the range of from about 40% to about 60% by weight of the liquid hardening agent component.

The silane coupling agent may be used, *inter alia*, to act as a mediator to help bond the resin to the sand surface. Examples of silane coupling agents that can be utilized in the

liquid hardening agent component of the two-component consolidation fluids of the present invention include, but are not limited to, n-2-(aminoethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane, and n-beta- (aminoethyl)-gamma-aminopropyl trimethoxysilane. The silane coupling agent used is included in the liquid hardening agent component in an amount capable of sufficiently bonding the resin to the particulate. In some embodiments of the present invention, the silane coupling agent used is included in the liquid hardenable resin component in the range of from about 0.1% to about 3% by weight of the liquid hardening agent component.

Any surfactant compatible with the liquid hardening agent may be used in the present invention. Such surfactants include, but are not limited to, ethoxylated nonyl phenol phosphate esters, mixtures of one or more cationic surfactants, and one or more non-ionic surfactants and alkyl phosphonate surfactants. The mixtures of one or more cationic and nonionic surfactants are described in U.S. Patent No. 6,311,733, the relevant disclosure of which is incorporated herein by reference. A  $C_{12}$  -  $C_{22}$  alkyl phosphonate surfactant is preferred. The surfactant or surfactants utilized are included in the liquid hardening agent component in an amount in the range of from about 2% to about 15% by weight of the liquid hardening agent component.

Use of a diluent or liquid carrier fluid in the hardenable resin composition is optional and may be used to reduce the viscosity of the hardenable resin component for ease of handling, mixing and transferring. It is within the ability of one skilled in the art, with the benefit of this disclosure, to determine if and how much liquid carrier fluid is needed to achieve a viscosity suitable to the subterranean conditions. Any suitable carrier fluid that is compatible with the hardenable resin and achieves the desired viscosity effects is suitable for use in the present invention. The liquid carrier fluids that can be utilized in the liquid hardening agent component of the two-component consolidation fluids of the present invention preferably include those having high flash points (most preferably above about 125°F). Examples of liquid carrier fluids suitable for use in the present invention include, but are not limited to, dipropylene glycol methyl ethers, dipropylene glycol dimethyl ethers, dimethyl formamides, diethyleneglycol methyl ethers, ethyleneglycol butyl ethers, diethyleneglycol butyl ethers, propylene carbonates, d'limonene and fatty acid methyl esters.

Another resin suitable for use in the methods of the present invention are furan-based resins. Suitable furan-based resins include, but are not limited to, furfuryl alcohol resins,

mixtures furfuryl alcohol resins and aldehydes, and a mixture of furan resins and phenolic resins. A furan-based resin may be combined with a solvent to control viscosity if desired. Suitable solvents for use in the furan-based consolidation fluids of the present invention include, but are not limited to 2-butoxy ethanol, butyl acetate, and furfuryl acetate.

Still another resin suitable for use in the methods of the present invention are phenolic-based resins. Suitable phenolic-based resins include, but are not limited to, terpolymers of phenol, phenolic formaldehyde resins, and a mixture of phenolic and furan resins. A phenolic-based resin may be combined with a solvent to control viscosity if desired. Suitable solvents for use in the phenolic-based consolidation fluids of the present invention include, but are not limited to butyl acetate, butyl lactate, furfuryl acetate, and 2-butoxy ethanol.

Another resin suitable for use in the methods of the present invention is a HT epoxy-based resin. Suitable HT epoxy-based components include, but are not limited to, bisphenol A-epichlorohydrin resins, polyepoxide resins, novolac resins, polyester resins, glycidyl ethers and mixtures thereof. An HT epoxy-based resin may be combined with a solvent to control viscosity if desired. Suitable solvents for use with the HT epoxy-based resins of the present invention are those solvents capable of substantially dissolving the HT epoxy-resin chosen for use in the consolidation fluid. Such solvents include, but are not limited to, dimethyl sulfoxide and dimethyl formamide. A co-solvent such as a dipropylene glycol methyl ether, dipropylene glycol dimethyl ether, dimethyl formamide, diethylene glycol methyl ether, ethylene glycol butyl ether, diethylene glycol butyl ether, propylene carbonate, d'limonene and fatty acid methyl esters, may also be used in combination with the solvent.

Yet another resin consolidation material suitable for use in the methods of the present invention is a phenol/phenol formaldehyde/furfuryl alcohol resin comprising from about 5% to about 30% phenol, from about 40% to about 70% phenol formaldehyde, from about 10 to about 40% furfuryl alcohol, from about 0.1% to about 3% of a silane coupling agent, and from about 1% to about 15% of a surfactant. In the phenol/phenol formaldehyde/furfuryl alcohol resins suitable for use in the methods of the present invention, suitable silane coupling agents include, but are not limited to, n-2-(aminoethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane, and n-beta-(aminoethyl)-gamma-aminopropyl trimethoxysilane. Suitable surfactants include, but are not limited to, an



ethoxylated nonyl phenol phosphate ester, mixtures of one or more cationic surfactants, and one or more non-ionic surfactants and an alkyl phosphonate surfactant.

A tackifying material may be also used in the methods and compositions of the present invention. Compounds suitable for use as a tackifying compound in the present invention comprise substantially any compound that, when in liquid form or in a solvent solution, will form a non-hardening, sticky coating upon particulates. A particularly preferred group of tackifying compounds comprise polyamides that are liquids or in solution at the temperature of the subterranean formation such that the polyamides are, by themselves, non-hardening when present on the particulates introduced into the subterranean formation. A particularly preferred product is a condensation reaction product comprised of commercially available polyacids and a polyamine. Such commercial products include compounds such as mixtures of  $C_{36}$  dibasic acids containing some trimer and higher oligomers and also small amounts of monomer acids that are reacted with polyamines. Other polyacids include trimer acids, synthetic acids produced from fatty acids, maleic anhydride and acrylic acid and the like. Such acid compounds are commercially available from companies such as Witco Corporation, Union Carbide, Chemtall, and Emery Industries. The reaction products are available from, for example, Champion Technologies, Inc. and Witco Corporation. Additional compounds which may be utilized as tackifying compounds include liquids and solutions of, for example, polyesters, polycarbonates and polycarbamates, natural resins such as shellac and the like. Suitable tackifying compounds are described in U.S. Patent Number 5,853,048 issued to Weaver, et al. and U.S. Patent Number 5,833,000 issued to Weaver, et al., the disclosures of which are herein incorporated by reference.

Any particulate suitable for use in subterranean applications is suitable for use in the compositions and methods of the present invention. For instance, natural sand, ground walnut hulls, man-made proppants, including bauxite, ceramics, polymeric materials, or the like are suitable. Suitable sizes range from 4 to 100 U.S. mesh, but are preferably in the range of 10 to 60 US mesh. The particulate material may be combined with the consolidation material either on-the-fly or may be combined in ahead of schedule and brought to the well site.

In some embodiments of the present invention, once the hydramjetting and placement of the consolidating material is complete, an expandable screen may be placed in the well bore. One skilled in the art, with the benefit of this disclosure, will be able to determine

when it is advantageous to use such an expandable screen. For example, the isolated well bore section may be either cased or uncased. Where the present invention is used on an uncased isolated zone, an expandable screen may be necessary used to control the formation sands surrounding the isolated zone. Moreover, as a tackifying material does not harden and cannot be guaranteed to permanently consolidate particulates such as proppant, where the consolidating fluid chosen is a tackifying material an expandable screen may be necessary to control not only the migration of formation sands, but also the migration of proppant.

Where an expandable screen is used, its openings should be sized based on its application. For example, when used in an uncased well bore, the openings in the expandable screen should be sized based on the size of the proppant and the size of the formation sands to be controlled. Where an expandable screen is used in a cased well bore, only the size of the proppant need be considered.

One embodiment of a method of the present invention provides a method of controlling the migration of formation sand in a well bore and increasing formation permeability comprising the steps of isolating a zone of interest along a well bore, hydrazetting at least one slot in the zone of interest, and contemporaneously filling the slot with a consolidation material and proppant.

Therefore, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned as well as those that are inherent therein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit and scope of this invention as defined by the appended claims.

What is claimed is:

1. A method of controlling the migration of formation sand in a well bore and increasing surface area for well production comprising the steps of:
  - (a) hydramjetting at least one slot into a zone along a well bore; and
  - (b) placing a consolidation material comprising particulates into the slot.
2. The method of claim 1 further comprising the step of, after step (b):
  - (c) placing and expanding an expandable screen in the isolated zone of the well bore.
3. The method of claim 1 wherein the consolidation material comprises a resin.
4. The method of claim 3 wherein the resin consolidation material comprises a hardenable resin component comprising a hardenable resin and a hardening agent component comprising a liquid hardening agent, a silane coupling agent, and a surfactant.
5. The method of claim 4 wherein the hardenable resin in the liquid hardenable resin component is an organic resin comprising bisphenol A-epichlorohydrin resin, polyepoxide resin, novolak resin, polyester resin, phenol-aldehyde resin, urea-aldehyde resin, furan resin, urethane resin, glycidyl ethers, or mixtures thereof.
6. The method of claim 4 wherein the liquid hardening agent in the liquid hardening agent component comprises amines, aromatic amines, aliphatic amines, cycloaliphatic amines, piperidine, triethylamine, benzyldimethylamine, N,N-dimethylaminopyridine, 2-(N,N-dimethylaminomethyl)phenol, tris(dimethylaminomethyl)phenol, or mixtures thereof.
7. The method of claim 4 wherein the silane coupling agent in the liquid hardening agent component comprises N-2-(aminoethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane, n-beta-(aminoethyl)-gamma-aminopropyltrimethoxysilane or mixtures thereof.
8. The method of claim 4 wherein the surfactant in the liquid hardening agent component comprises ethoxylated nonyl phenol phosphate ester, mixtures of one or more cationic surfactants, a C<sub>12</sub> – C<sub>22</sub> alkyl phosphonate surfactant, one or more non-ionic surfactants and an alkyl phosphonate surfactant, or mixtures thereof.
9. The method of claim 4 wherein the resin consolidation material is a furan-based resin comprising furfuryl alcohol, a mixture furfuryl alcohol with an aldehyde, a mixture of furan resin and phenolic resin or mixtures thereof.

10. The method of claim 4 further comprising a solvent comprising 2-butoxy ethanol, butyl acetate, furfuryl acetate, or mixtures thereof.

11. The method of claim 3 wherein the resin consolidation material is a phenolic-based resin comprising terpolymer of phenol, phenolic formaldehyde resin, a mixture of phenolic and furan resin, or mixtures thereof.

12. The method of claim 11 further comprising a solvent comprising butyl acetate, butyl lactate, furfuryl acetate, 2-butoxy ethanol, or mixtures thereof.

13. The method of claim 3 wherein the resin consolidation material is a HT epoxy-based resin comprising bisphenol A-epichlorohydrin resin, polyepoxide resin, novolac resin, polyester resin, glycidyl ethers, or mixtures thereof.

14. The method of claim 13 further comprising a solvent comprising dimethyl sulfoxide, dimethyl formamide, dipropylene glycol methyl ether, dipropylene glycol dimethyl ether, dimethyl formamide, diethylene glycol methyl ether, ethylene glycol butyl ether, diethylene glycol butyl ether, propylene carbonate, d'limonene, fatty acid methyl esters, or mixtures thereof.

15. The method of claim 1 wherein the consolidation material comprises a tackifying material.

16. The method of claim 15 wherein the tackifying consolidation material is a polyamide, polyesters, polycarbonates, polycarbamates, natural resins, or combinations thereof.

17. The method of claim 2 wherein the well bore comprises a cased well bore.

18. The method of claim 17 wherein the size of the openings in the expandable screen is smaller than the average size of particulate used.

19. The method of claim 2 wherein the well bore comprises an uncased well bore.

20. The method of claim 17 wherein the size of the openings in the expandable screen is smaller than both the average size of particulate used and the average size of the formation sands.

21. A method of increasing production from a zone along a well bore comprising the steps of:

- (a) hydrajetting at least one slot into the zone along the well bore; and,
- (b) placing a consolidation material comprising particulates into the slot.

22. The method of claim 1 further comprising the step of, after step (b):  
(c) placing and expanding an expandable screen in the isolated zone of the well bore.
23. The method of claim 21 wherein the consolidation material comprises a resin.
24. The method of claim 23 wherein the resin consolidation material comprises a hardenable resin component comprising a hardenable resin and a hardening agent component comprising a liquid hardening agent, a silane coupling agent, and a surfactant.
25. The method of claim 24 wherein the hardenable resin in the liquid hardenable resin component is an organic resin comprising bisphenol A-epichlorohydrin resin, polyepoxide resin, novolak resin, polyester resin, phenol-aldehyde resin, urea-aldehyde resin, furan resin, urethane resin, glycidyl ethers, or mixtures thereof.
26. The method of claim 24 wherein the liquid hardening agent in the liquid hardening agent component comprises amines, aromatic amines, aliphatic amines, cyclo-aliphatic amines, piperidine, triethylamine, benzyldimethylamine, N,N-dimethylaminopyridine, 2-(N<sub>2</sub>N-dimethylaminomethyl)phenol, tris(dimethylaminomethyl)phenol, or mixtures thereof.
27. The method of claim 24 wherein the silane coupling agent in the liquid hardening agent component comprises N-2-(aminoethyl)-3-aminopropyltrimethoxysilane, 3-glycidoxypropyltrimethoxysilane, n-beta- (aminoethyl)-gamma-aminopropyl trimethoxysilane or mixtures thereof.
28. The method of claim 24 wherein the surfactant in the liquid hardening agent component comprises ethoxylated nonyl phenol phosphate ester, mixtures of one or more cationic surfactants, a C<sub>12</sub> – C<sub>22</sub> alkyl phosphonate surfactant, one or more non-ionic surfactants and an alkyl phosphonate surfactant, or mixtures thereof.
29. The method of claim 24 wherein the resin consolidation material is a furan-based resin comprising furfuryl alcohol, a mixture furfuryl alcohol with an aldehyde, a mixture of furan resin and phenolic resin or mixtures thereof.
30. The method of claim 24 further comprising a solvent comprising 2-butoxy ethanol, butyl acetate, furfuryl acetate, or mixtures thereof.
31. The method of claim 23 wherein the resin consolidation material is a phenolic-based resin comprising terpolymer of phenol, phenolic formaldehyde resin, a mixture of phenolic and furan resin, or mixtures thereof.

32. The method of claim 31 further comprising a solvent comprising butyl acetate, butyl lactate, furfuryl acetate, 2-butoxy ethanol, or mixtures thereof.

33. The method of claim 23 wherein the resin consolidation material is a HT epoxy-based resin comprising bisphenol A-epichlorohydrin resin, polyepoxide resin, novolac resin, polyester resin, glycidyl ethers, or mixtures thereof.

34. The method of claim 33 further comprising a solvent comprising dimethyl sulfoxide, dimethyl formamide, dipropylene glycol methyl ether, dipropylene glycol dimethyl ether, dimethyl formamide, diethylene glycol methyl ether, ethylene glycol butyl ether, diethylene glycol butyl ether, propylene carbonate, d'limonene, fatty acid methyl esters, or mixtures thereof.

35. The method of claim 21 wherein the consolidation material comprises a tackifying material.

36. The method of claim 35 wherein the tackifying consolidation material is a polyamide, polyesters, polycarbonates, polycarbamates, natural resins, or combinations thereof.

37. The method of claim 22 wherein the well bore comprises a cased well bore.

38. The method of claim 37 wherein the size of the openings in the expandable screen is smaller than the average size of particulate used.

39. The method of claim 22 wherein the well bore comprises an uncased well bore.

40. The method of claim 37 wherein the size of the openings in the expandable screen is smaller than both the average size of particulate used and the average size of the formation sands.

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
10 March 2005 (10.03.2005)

PCT

(10) International Publication Number  
**WO 2005/021928 A3**

- (51) International Patent Classification<sup>7</sup>: **E21B 33/138**, 43/25, 43/08, 43/02, 43/114, 43/26
- (21) International Application Number: **PCT/GB2004/002747**
- (22) International Filing Date: **25 June 2004 (25.06.2004)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data: **10/650,064** **26 August 2003 (26.08.2003)** **US**
- (71) Applicant (for all designated States except US): **HAL-LIBURTON ENERGY SERVICES, INC. [US/US]; P.O. Box 1431, Duncan, OK 73533 (US).**
- (71) Applicant (for MW only): **WAIN, Christopher, Paul [GB/GB]; A.A. Thornton & Co., 235 High Holborn, London WC1V 7LE (GB).**
- (72) Inventor; and
- (75) Inventor/Applicant (for US only): **NGUYEN, Philip, D. [US/US]; 1107 West Jones Avenue, Duncan, OK 73533 (US).**
- (74) Agents: **WAIN, Christopher, Paul et al.; A A Thornton & Co, 235 High Holborn, London WC1V 7LE (GB).**
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): **AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.**
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): **ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).**
- Published:**
- with international search report
  - before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
- (88) Date of publication of the international search report:  
**12 May 2005**
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: **PRODUCTION-ENHANCING COMPLETION METHODS**

(57) Abstract: The present invention relates to improved methods for completing well bores along producing zones while controlling formation sands and increasing surface area available for production. Some embodiments of the methods of the present invention provide methods of controlling the migration of formation sand in a well bore and increasing surface area for well production comprising the steps of hydrajetting at least one slot into a zone along a well bore; and, placing a consolidation material comprising particulates into the slot.

**WO 2005/021928 A3**

# INTERNATIONAL SEARCH REPORT

Int'l Application No  
PCT/GB2004/002747

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B33/138 E21B43/25 E21B43/08 E21B43/02 E21B43/114  
E21B43/26

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 C08K C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 864 726 A (HALLIBURTON ENERGY SERVICES, INC) 16 September 1998 (1998-09-16)  column 1, line 3 - line 7 column 2, line 41 - column 5, line 14	1-7, 13, 14, 17, 19, 21, 23-27, 33, 34, 37, 39
X	US 4 694 905 A (ARMBRUSTER ET AL) 22 September 1987 (1987-09-22)  column 2, line 51 - column 4, line 40  -/-	1, 3-5, 7, 9, 11, 21, 24, 25, 29, 31

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

### \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*G\* document member of the same patent family

Date of the actual completion of the international search

2 March 2005

Date of mailing of the international search report

11/03/2005

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Boulon, A



## INTERNATIONAL SEARCH REPORT

Int. Application No  
PCT/GB2004/002747

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 042 032 A (ANDERSON ET AL) 16 August 1977 (1977-08-16) column 1, line 10 - line 35 column 2, line 46 - line 64 column 3, line 31 - column 4, line 8 column 4, line 46 - column 6, line 41 column 7, line 25 - line 30 column 7, line 60 - column 8, line 15; examples I, VI	1,3-9, 21,23-29
P,X	EP 1 403 466 A (HALLIBURTON ENERGY SERVICES, INC) 31 March 2004 (2004-03-31)  paragraph '0003! paragraph '0008! - paragraph '0009! paragraph '0017! - paragraph '0022! paragraph '0031!	1,3-8, 13,14, 21, 23-28, 33,34

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No  
PCT/JP2004/002747

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0864726	A	16-09-1998	US 5791415 A CA 2232051 A1 DE 69820138 D1 DE 69820138 T2 DK 864726 T3 EP 0864726 A2 NO 981102 A	11-08-1998 13-09-1998 15-01-2004 27-05-2004 22-03-2004 16-09-1998 14-09-1998
US 4694905	A	22-09-1987	CA 1279534 C	29-01-1991
US 4042032	A	16-08-1977	DE 2425312 A1 DE 2462298 A1 DK 303874 A EG 12072 A ES 427058 A1 FR 2232672 A1 GB 1453001 A IE 39396 B1 IT 1012850 B MY 23277 A NL 7407104 A NO 742043 A , B, SE 408655 B SE 7407564 A	16-01-1975 09-09-1976 20-01-1975 30-09-1978 16-07-1976 03-01-1975 20-10-1976 27-09-1978 10-03-1977 31-12-1977 10-12-1974 06-01-1975 25-06-1979 09-12-1974
EP 1403466	A	31-03-2004	US 2004000402 A1 CA 2441332 A1 EP 1403466 A2 MX PA03008796 A US 2003188872 A1 US 2004221992 A1	01-01-2004 30-03-2004 31-03-2004 15-04-2004 09-10-2003 11-11-2004